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FOLIAGE DRY MATTER OF PINUS MONTICOLA;

ITS VARIABILITY WITH ENVIRONMENT
AND BLISTER RUST RESISTANCE

CURRENT SERIAL RECORDS

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ABSTRACT

Foliage dry-matter content was measured to determine its association with western white pines (Pinus monticola Dougl.) that are resistant and susceptible to blister rust (causal organism Cronartium ribicola J.C. Fisch. ex. Rabenh.). No significant difference between blister rust resistant and susceptible trees was found, even though environmental influences, including rust infection, were largely eliminated.

Dry-matter content of foliage is occasionally used as a limited indicator for photosynthetic activity in individual crop plants as well as in stands (Schwarze 1958). In forest trees, Langlet (1936) found that percentage dry matter of foliage varied according to the seed source of the tree in Scotch pine (Pinus sylvestris L.). This relationship, moreover, was closely associated with frost hardiness.

Resistance to infection by micro-organisms has also been shown to be closely tied to the water balance of plant tissues. Gaskill (1950) has shown that sugar beets with a high moisture content were relatively more resistant to storage decay. Further, the susceptibility of poplar bark to Dothichiza populea Sacc. and Br. increases with reduction of water content (Butin 1957). Resistance in poplar to D. populea appears to be associated with the rate of formation of wound epiphloem. Apparently, resistance was decreased because of a weakening of the synthetic processes that lead to formation of wound peridermal tissues.

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Three times, in the course of other work at the Moscow, Idaho, laboratory,^{2 3} western white pine (*Pinus monticola* Dougl.) from natural stands has been studied to determine the relationship between percentage dry-matter content of foliage and resistance or susceptibility to blister rust (*Cronartium ribicola* J.C. Fisch. ex Rabenh.). In these comparisons, the susceptible trees were infected in various degrees; however, the foliage analyzed was healthy and was collected from branches without cankers. In all three investigations, resistant selections were found to have on the average a lower percentage of dry matter--approaching significance at the 5-percent level. Therefore, in order to secure more conclusive evidence, we decided to test variation of foliage dry-matter content in relation to rust resistance on a broader base of materials while holding sampling techniques and environmental factors constant. Thus, included in this study are within- and between-tree environmental variations.

METHODS

Two types of plant materials were used. These were grafted clones and 10- to 15-year-old trees growing in an arboretum. Because the amount of foliage on the clones was limited, eight 1-year-old needle bundles (40 needles) were selected as an optimal sample size.

To minimize percentage dry-weight errors arising from differential evaporation, all the samples were put on dry ice immediately after collection and kept there for 24 hours. Preliminary tests showed that dry-ice storage caused a moisture loss that resulted in a 2- to 3-percent increase of dry weight, which occurred mainly during the first 30 minutes after sampling. Since all tested individuals reacted uniformly in this respect, the possibility of comparison remained unchanged.

Dry weight was determined by drying the needles in an oven at 105°C. Samples were weighed after 24 hours and daily thereafter, to an accuracy of 0.1 mg. Constancy of weight could not be obtained within 7 days. However, because in every sample tested dry weight decreased slowly and uniformly from the second day on, dry weight after 72 hours in the oven was used in this study.

DETERMINATION OF WITHIN-TREE VARIATION

As a preliminary to the main investigation, it was necessary to study the range of within-tree variation so as to determine a sampling method that might isolate variations related to rust resistance. Needle samples from different parts of 10- to 15-year-old open-grown trees were analyzed, using the methods described above. The following sources of variation were considered. For variation due to side of crown, needles were taken from the north, south, east, and west, and because of the higher shading effects on the north, samples were also collected from the northeast and northwest sides. For crown depth, needles from the outer (the distal portion of the branches) were compared with the inner crown (the proximal portion of the branches). For crown height, comparisons were made among the upper, middle, and lower portions of the crown. For needle age, comparisons were made between first and second year needles. For needle depth, comparisons were made of needles from the distal portion to the proximal portion of a stem of 1 year's wood.

²Hanover, J. W. Comparative biochemistry and physiology of western white pine (*Pinus monticola* Dougl.) resistant and susceptible to infection by the blister rust fungus (*Cronartium ribicola* Fischer). Ph.D. Thesis, Wash. State Univ., Pullman, Wash. 176 pp. 1963.

³Hoff, R. J. Comparative physiology of *Pinus monticola* Dougl. resistant and susceptible to *Cronartium ribicola* J.C. Fisch. ex Rabenh. Ph.D. Thesis, Wash. State Univ., Pullman, Wash. 76 pp. 1968.

Table 1.--Within-tree variation in dry-matter content of needles
of Pinus monticola

Source of variation	Range of dry-matter content	Tendency	Number of trees
	<u>Percent</u>		
Crown side (N:E:S:W:)	2.5**	S>W or E>N	9
Crown side (NW:N:NE)	1.0	NE>N or NW	3
Crown depth (inner: outer crown)	2.2**	Outer>inner	4
Crown height	3.1**	Upper>lower	4
Needle age	1.5*	2-year>1-year	9
Needle depth	1.8*	distal>proximal	4

* Significant at the 0.05 level of probability, paired t test.

** Significant at the 0.01 level of probability.

The variation was significant for most of the comparisons made, particularly in respect to the difference in the amount of light to which the sampled needles had been exposed (table 1). Without exception, needles from a sunny part of the crown had less dry matter than shaded needles.

Twig order (leaders vs. laterals) was found to be another source of variation. Whereas some of these trees had higher values for foliage dry matter in the twigs of second order, others showed the opposite tendency, and a third group did not show any differences. The average percent foliage dry matter based on 10 trees was 46.8 for both twig orders. The range was 44.6-49.2 for the first twig order and 45.6-48.7 for the second twig order.

Since dry-matter production, among other factors, is influenced by photosynthesis and transpiration, and since there are many examples of diurnal variation for both photosynthetic activity (Ståfeldt 1960) and transpiration (Walter 1960), there was little doubt that percent dry weight of western white pine would follow a particular diurnal rhythm.

This supposition was shown to be justified on 10 trees studied under various weather conditions. Generally, a small increase could be observed from 10:00 a.m. to 12:00 noon, and a more pronounced decrease was evident for the later afternoon. This tendency, however, varied with weather conditions and from tree to tree. On the other hand, there was a close relationship in the curves of diurnal fluctuation of foliage dry matter between 1- and 2-year-old needles of the same tree. These conclusions suggested that trees should be sampled during the hours of smallest variation. Most frequently this was the period between 8:00 and 10:00 a.m.

Because of the high within-tree variation, the sampling procedure applied in the main study was strictly standardized: from 8:00 to 10:00 a.m. eight 2-year-old needle fascicles were taken from the north side, at the middle of the crown (3-5 ft. high), and the inner portion of the internode.

DETERMINATION OF VARIATION BETWEEN TREES OF VARYING RESISTANCE

Grafts and seedlings of a known degree of resistance against the blister rust fungus were compared in respect to their foliage dry-matter content at four locations in northern Idaho.

GRAFTS

Needle samples were taken from 4-year-old grafts of four resistant and four nonresistant clones, outplanted at Moscow, Idaho; Emerald Creek (4 miles west of Clarkia, Idaho); and Sandpoint, Idaho, and analyzed during July 1966. Except for shelter, the ecological conditions within a plot were fairly uniform.

SEEDLINGS

Further comparisons were carried out with 10- to 15-year-old F_1 progenies from parent trees with either high or low combining ability for rust resistance (Bingham, Squillace, and Wright 1960). The material was located in the "Moscow Arboretum," a hilly, wind-exposed area located 1 mile west of Moscow, Idaho.

INFECTED VS. UNINFECTED PLANTS

In order to determine whether differences in dry-matter content between resistant and susceptible trees found in previous studies could be attributed to the presence or absence of the pathogen in the host tissue, a final series of 10 pairs of trees was selected from the arboretum. Both trees of a pair grew close together (from 40 to 400 ft., average 155 ft.) and both belonged to the same F_1 combination; one, however, had stem cankers and the other one was healthy.

RESULTS

In the studies of grafts from resistant and nonresistant clones, even small differences in the amounts of shelter or shade led to remarkable variation in foliage dry matter.

Although individual variation was apparent, there was no indication of a difference in dry-matter content between resistant and susceptible clones (table 2). The high variation between ramets of the same clone was the most pronounced feature of the data. A later analysis of the same material (November 1966) gave similar results. Although the dry weight had generally decreased from 3 to 4 percent, there was still a large intraclonal variation, and again no indication of a relationship between resistance and dry-matter level could be found.

After several comparative samples of the 10- to 15-year-old seedlings were analyzed, a lower dry-matter content for resistant seedlings could be observed. However, because of a high intrafamily variation, these differences were not significant. Even when the conditions of wind- and light-exposure of the sampled trees were relatively uniform, the dry-matter difference between resistant and susceptible combinations was not found to be significant at the $P = 0.05$ level.

In the study of infected and uninfected plants, in spite of a wide variation in the dry-matter content of infected and uninfected plants, no consistent difference was found between pairs. On the average, the infected trees did not differ from the rust-free ones with respect to dry matter (41.16%:41.24%).

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Table 2.--Range and mean of percent foliage dry matter from 4-year-old grafts of four resistant (R) and four nonresistant (NR) clones¹ planted in three locations in Idaho and sampled July 19, 1966

Clone	Moscow		Emerald Creek		Sandpoint		Grand mean
	Range	Mean	Range	Mean	Range	Mean	
NR 1	40.5-42.7	41.3	43.8-46.9	45.4	² 41.6-41.8	41.7	
NR 2	--	--	³ 42.3-45.1	44.1	--	--	
NR 3	42.0-43.3	42.7	43.0-44.6	44.2	40.5-41.6	41.2	
NR 4	38.9-42.0	40.4	41.0-44.0	42.7	³ 41.2-44.3	42.1	
Mean		41.4		44.1		41.8	42.4
R 19	39.0-43.3	40.5	40.9-46.7	43.3	38.4-40.9	40.0	
R 22	39.7-44.3	42.3	41.4-48.7	44.9	42.6-44.6	43.5	
R 24	40.8-43.5	42.3	41.6-43.9	42.9	³ 41.8-43.8	42.6	
R 58	40.7-42.6	41.6	44.2-45.5	44.9	39.4-42.1	41.1	
Mean		41.7		43.9		41.7	42.4

¹Data cover four ramets in each clone except as noted otherwise.

²Two ramets only.

³Three ramets only.

CONCLUSIONS

Comparisons between foliage dry-matter data of different *P. monticola* trees are complicated by a large within-tree variability, for which light intensity seems to be a controlling factor. By strict standardization of sampling procedure, this source of error can be considerably reduced.

Differences of up to 1.5 percent in foliage dry matter were found between blister rust resistant and susceptible plants in F₁ progenies of known combining ability; however, they were not significant because of a broad variation within the families. On the other hand, similar comparisons between grafts did not show this difference at all, nor did comparisons between rust-cankered and healthy trees.

These findings lead to the conclusion that foliage dry-matter content of *P. monticola* is not a reliable indicator of the degree of rust resistance, at least not under the field conditions tested. Strong influences of environmental factors such as water supply, light, and wind, as well as genetic diversity of the seedling material, remain as big obstacles to progress that will be difficult to overcome. Also, resistance against blister rust is possibly a rather complex genetic character. Beyond the percentage of surviving seedlings from resistant parents, relatively little is known about the nature of the resistance mechanisms. Perhaps only one of several factors is correlated with dry-matter content or maybe none at all. Possibly, similar investigations during the period of dormancy or under greenhouse conditions may give better results.

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